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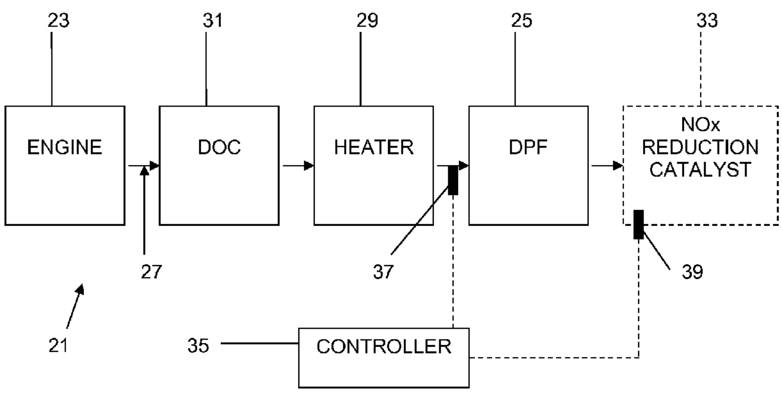


FIG. 1

(57) Abstract: A system for treating diesel exhaust gases includes an engine for producing a diesel exhaust stream, a diesel particulate filter downstream of the engine and adapted to remove particulates from the exhaust stream, a heater upstream of the filter adapted to deliver energy in sufficient amounts to the exhaust stream to cause active regeneration of the filter, and a diesel oxidation catalyst upstream of the heater adapted to cause passive regeneration of the filter when the exhaust stream is above a light-off temperature of the diesel oxidation catalyst. A NOx reduction catalyst can be provided downstream of the heater. Methods for treating diesel exhaust gases are also disclosed.

WO 2009/123633 A1

SYSTEM AND METHOD FOR TREATING DIESEL EXHAUST GASES

BACKGROUND AND SUMMARY

The present invention relates, generally, to systems and methods for treating diesel exhaust gases and, more particularly, to systems and methods for treating non-stationary diesel exhaust gases.

Diesel engines tend to have low emissions of gas phase hydrocarbons and carbon monoxide, however, they tend to have relatively high emissions of nitrogen oxides (NOx) and particulates. As standards for NOx and particulate emissions become more stringent, it is increasingly important to devise strategies for reducing these emissions.

In diesel engines, a DPF can be used downstream of the engine to filter particulates from the engine exhaust. If too much soot collects in the DPF, the soot can burn in an uncontrolled manner and may crack or melt the DPF. This phenomenon is sometimes referred to as a "runaway" or uncontrolled regeneration. Other problems can result from excessive soot accumulation in the DPF as well, such as an increase in engine backpressure, which can have an adverse effect on engine operation and affect fuel consumption.

To avoid aforementioned problems such as runaway regenerations, the DPF is periodically cleaned by burning off the soot, through a so-called active regeneration operation in a controlled manner that does not ordinarily do serious damage the DPF. Carbon in the filter reacts with NO_2 in the exhaust gas stream by the reactions $NO_2 + C \rightarrow NO + CO$ and $2NO_2 + 2C \rightarrow N_2 + CO_2$. To achieve the desirable reaction, $2NO_2 + 2C \rightarrow N_2 + CO_2$, the carbon soot particles typically require temperatures in excess of 500-550 °C. Those temperatures are much higher than typical diesel exhaust temperatures.

A solution to this problem is to install a heater, such as a burner or electrical coils, upstream of the DPF to raise the exhaust stream temperature to a temperature suitable for regeneration, a technique typically referred to as "active" regeneration. Active regeneration results in some efficiency losses and thermal stress on the filter, and it is desirable to limit its use. Also, care must be taken to ensure that "runaway" regeneration, essentially uncontrolled combustion, does not occur and cause damage to the filter.

An alternative to active regeneration is so-called passive regeneration. The reaction between the accumulated particles and oxygen in the exhaust stream (usually in the form of O_2 and NO_2) ordinarily naturally results in some of the particles oxidizing. However, at ordinary exhaust temperatures, passive regeneration generally occurs too slowly to remove accumulated particles. To provide sufficient passive regeneration to keep the DPF operating efficiently, a catalyst can be used. The catalyst can be a so-called diesel oxidation catalyst (DOC) that can be provided upstream of or on the DPF and causes NO in the exhaust stream to convert to NO_2, thereby facilitating passive regeneration when the NO_2 reacts with the particles in the DPF.

To reduce NOx emissions, NOx catalysts such as selective catalytic reduction catalysts (SCR) or lean NOx catalysts (LNC) can be provided in the exhaust stream. SCR catalysts are presently most common and can be very efficient at reducing NOx emissions to N_2 using NH_3 over a catalyst such as zeolite or V/Ti. However, these catalysts typically operate most efficiently at relatively high temperatures, such as >300 ºC, which is often above the exhaust temperature for a diesel engine used in a vehicle application.

It is desirable to provide a system and method for treating diesel exhaust gases that can efficiently remove particulate matter and reduce NOx emissions.

According to an aspect of the present invention, a system for treating diesel exhaust gases comprises an engine for producing a diesel exhaust stream, a diesel particulate filter downstream of the engine and adapted to remove particulates from the exhaust stream, a heater upstream of the filter adapted to deliver energy in sufficient amounts to the exhaust stream to cause active regeneration of the filter, and a diesel oxidation catalyst upstream of the heater adapted to cause passive regeneration of the filter when the exhaust stream is above a light-off temperature of the diesel oxidation catalyst.

According to another aspect of the invention, a system for treating diesel exhaust gases comprises an engine for producing a diesel exhaust stream, a diesel particulate filter downstream of the engine and adapted to remove particulates from the exhaust stream, a heater upstream of the filter adapted to deliver energy to the exhaust stream, and a NOx reduction catalyst downstream of the heater.

According to yet another aspect of the invention, a method for treating diesel exhaust gases comprises producing a diesel exhaust stream with a diesel engine, removing particulates from the exhaust stream with a diesel particulate filter downstream of the engine, periodically delivering energy from a heater to the exhaust stream upstream of the filter in sufficient amounts to cause active regeneration of the filter, and periodically heating a diesel oxidation catalyst upstream of the heater to a light-off temperature of the diesel oxidation catalyst to cause passive regeneration of the filter.

According to still another aspect of the invention, a method for treating diesel exhaust gases comprises producing a diesel exhaust stream with a diesel engine, removing particulates from the exhaust stream with a diesel particulate filter downstream of the engine, causing NOx reduction in the exhaust stream with a NOx reduction catalyst, and delivering energy from a heater upstream of the NOx reduction catalyst sufficient to raise a temperature of the NOx reduction catalyst to a temperature in an optimal range for NOx reduction by the NOx reduction catalyst.

BRIEF DESCRIPTION OF THE DRAWING

The features and advantages of the present invention are well understood by reading the following detailed description in conjunction with the drawing in which like numerals indicate similar elements and in which:

FIG. 1 is a schematic view of a system for treating diesel exhaust gases according to an aspect of the present invention; and

FIG. 2 is a schematic view of a system for treating diesel exhaust gases according to another aspect of the present invention.

DETAILED DESCRIPTION

A system for treating diesel exhaust gases according to an aspect of the present invention is seen in FIG. 1. The system 21 includes an engine 23 for producing a diesel exhaust stream. A diesel particulate filter (DPF) 25 is disposed in an exhaust line 27 downstream of the engine and is adapted to remove particulates from the exhaust stream. A heater 29 is disposed upstream of the DPF 25 and is adapted to deliver energy in sufficient amounts to the exhaust stream to cause active regeneration of the DPF. The heater 29 can be of any suitable type, such as a burner, electrical coils, or a diesel oxidation catalyst.

A diesel oxidation catalyst (DOC) 31 is disposed upstream of the heater 29 and is adapted to cause passive regeneration of the DPF when the exhaust stream is above a light-off temperature of the DOC. If the heater 29 includes a diesel oxidation catalyst, the DOC 31 is a different diesel oxidation catalyst. A diesel oxidation catalyst forming part or all of the heater 29 will be of a type adapted to raise temperatures upstream of the DPF 25 to temperatures sufficient to cause active regeneration. The DOC 31 will typically be of a type that is adapted to cause NO in the exhaust stream to form NO_2, usually at ordinary diesel exhaust temperatures.

In the system 21 according to this aspect, regeneration of the DPF 25 can occur through passive regeneration when exhaust stream temperatures are above the light-off temperature of the DOC 31 and, when exhaust stream temperatures are too low to permit for adequate passive regeneration, the heater 29 can be operated to cause active regeneration. It is ordinarily desirable to increase exhaust stream temperatures to about 650 °C upstream of the DPF 25 for active regeneration, however, an oxidation catalyst can be provided on the DPF, in which case temperature of the exhaust stream can be lower, such as around 600-625 °C.

A NOx reduction catalyst 33 (shown in phantom) can be provided downstream of the heater 29. The NOx reduction catalyst 33 will ordinarily be provided downstream of the DPF 25. The heater 29 can be adapted to elevate the exhaust stream temperature to a temperature in an optimal range for NOx reduction by the catalyst, such as a temperature greater than 300 °C. When an oxidation catalyst is provided on the DPF 25, it can be of a type designed to produce a desired ratio of the NO/NO_2 (usually about 1:1) for a fast, low temperature NOx reduction across the NOx reduction catalyst. Providing an oxidation catalyst on the DPF 25 can lower the temperature required for active regeneration of the DPF, and can condition the exhaust gas going into the NOx reduction catalyst 33. In addition, the oxidation catalyst on the DPF 25 can be formulated to increase passive regeneration activity in the DPF when the catalyst light-off temperature is met, regardless whether there is DOC upstream of the heater.

A controller 35, such as a suitable computer, can be provided for controlling operation of the heater 29. A temperature sensor 37 can be provided for sensing a temperature in the exhaust stream. The temperature sensor 37 can send a signal corresponding to the temperature in the exhaust stream to the controller 35, and the controller can control the heater in response to the temperature signal. For example, if the temperature sensor 37 sends a signal to the controller 35 corresponding to a temperature below the light-off temperature of the DOC, and the controller determines that the temperature has been below the light-off temperature for a sufficient period of time (not necessarily a continuous length of time) such that, according to models for the particular system which may consider other factors such as backpressure, it is expected that regeneration of the DPF 25 is required, the controller can initiate control the heater 29 to deliver energy sufficient to cause active regeneration of the DPF.

A signal to the controller 35 from the temperature sensor 37 can also be used to cause the controller to control the heater 29 to deliver only enough energy to elevate the exhaust stream temperature to an optimal temperature range for NOx reduction. The controller 35 may also receive a signal from a NOx sensor 39 that can provide a signal to the controller to cause the controller to control the heater 29 to deliver sufficient heat to the exhaust stream to reduce the NOx level. The controller 35 can control the heater 29 in response to a variety of signals and inputs, including one or both of temperature and NOx levels from the temperature sensor 38 and the NOx sensor 39. There can, of course, be multiple temperature sensors, multiple NOx sensors, and multiple other sensors throughout the system 21 and the heater 29 can be controlled to optimize catalyst performance or regeneration as required.

In a method for treating diesel exhaust gases according to an aspect of the invention, a diesel exhaust stream is produced and particulates are removed from the exhaust stream with a diesel particulate DPF 25 downstream of the engine 23. A heater 29 periodically delivers energy to the exhaust stream upstream of the DPF 25 in sufficient amounts to cause active regeneration of the DPF. A DOC 31 upstream of the heater 29 is periodically heated to a light-off temperature of the DOC to cause passive regeneration of the DPF. The DOC 31 can be heated to the light-off temperature by any suitable means, such as by increasing the load on the engine 23 so that the engine exhaust stream is hotter, or heating the exhaust stream with another heater (not shown). A NOx reduction catalyst 33 can be provided to remove NOx from the exhaust stream downstream of the heater 29.

A temperature in the exhaust stream can be sensed by the temperature sensor 37 which can send a signal corresponding to the temperature in the exhaust stream to the controller 35 for controlling operation of the heater 29. The heater 29 can be controlled by the controller 35 in response to the temperature signal for tuning the temperature of the exhaust stream to achieve optimal DPF 25 regeneration temperatures (whether for a catalyzed or uncatalyzed DPF) and/or optimal temperatures for NOx reduction by the particular NOx reduction catalyst 33.

FIG. 2 shows a system 121 for treating diesel exhaust gases according to another aspect of the present invention. The system 121 includes an engine 123 for producing a diesel exhaust stream, a DPF 125 in an exhaust line 127 downstream of the engine and adapted to remove particulates from the exhaust stream, a heater upstream 129 of the DPF adapted to deliver energy to the exhaust stream, and a NOx reduction catalyst 133 downstream of the heater.

The system 121 can be arranged to tune the amount of energy delivered to the exhaust stream by the heater 129 to achieve optimal performance of the NOx reduction catalyst 133. In addition to being able to deliver sufficient energy to the exhaust stream to optimize performance of the NOx reduction catalyst, the heater 129 can be arranged to tune the amount of energy delivered to the exhaust stream by the heater to cause active regeneration of the DPF 125, usually about 650 °C upstream of the DPF for an uncatalyzed DPF and about 600-626 °C for a catalyzed DPF having a diesel oxidation catalyst coating.

A DOC 131 (shown in phantom) can be provided upstream of the heater 129. The DOC 131 can be adapted to cause passive regeneration of the DPF 125 when the exhaust stream is above a light-off temperature of the DOC.

A controller 135 can be provided for controlling operation of the heater 129. A temperature sensor 137 can be provided for sensing a temperature in the exhaust stream and sending a signal corresponding to the temperature in the exhaust stream to the controller 135. The controller 135 can control the heater 129 in response to the temperature signal to achieve optimal performance of the NOx reduction catalyst and/or to cause active regeneration of the DPF. Other sensors, such as a NOx sensor 139, can be provided to provide input to the controller 135 for determining when operation of the heater 129 should be initiated, usually based upon modeling for the particular system involved.

In a method for treating diesel exhaust gases according to an aspect of the present invention, a diesel exhaust stream is produced by an engine 123. Particulates are removed from the exhaust stream with the diesel particulate DPF 125 downstream of the engine 123. The NOx reduction catalyst 133 reduces NOx emissions in the exhaust stream. Energy can be delivered to the exhaust stream from a heater 129 upstream of the NOx reduction catalyst 133 sufficient to raise a temperature of the NOx reduction catalyst to a temperature in an optimal range for NOx reduction by the NOx reduction catalyst. Energy can also/instead be delivered to the exhaust stream from the heater 129 in sufficient amounts to elevate the temperature of the exhaust stream to a temperature sufficient to cause active regeneration of the DPF 125. A controller 135 can control operation of the heater 129 to tune delivery of energy to the exhaust gas stream to obtain optimal temperatures for NOx reduction and/or to reach temperatures for active regeneration of the DPF 125.

In the present application, the use of terms such as “including” is open-ended and is intended to have the same meaning as terms such as “comprising” and not preclude the presence of other structure, material, or acts. Similarly, though the use of terms such as “can” or “may” is intended to be open-ended and to reflect that structure, material, or acts are not necessary, the failure to use such terms is not intended to reflect that structure, material, or acts are essential. To the extent that structure, material, or acts are presently considered to be essential, they are identified as such.

While this invention has been illustrated and described in accordance with a preferred embodiment, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.

WHAT IS CLAIMED IS:

1. A system for treating diesel exhaust gases, comprising:

an engine for producing a diesel exhaust stream;

a diesel particulate filter downstream of the engine and adapted to remove particulates from the exhaust stream;

a heater upstream of the filter adapted to deliver energy in sufficient amounts to the exhaust stream to cause active regeneration of the filter; and

a diesel oxidation catalyst upstream of the heater adapted to cause passive regeneration of the filter when the exhaust stream is above a light-off temperature of the diesel oxidation catalyst.

2. The system as set forth in claim 1, comprising a NOx reduction catalyst downstream of the heater.

3. The system as set forth in claim 2, wherein the NOx reduction catalyst includes a catalyst downstream of the DPF.

4. The system as set forth in claim 2, wherein the heater is adapted to elevate the exhaust stream temperature to a temperature in an optimal range for NOx reduction by the catalyst.

5. The system as set forth in claim 2, comprising a controller for controlling operation of the heater and a temperature sensor for sensing a temperature in the exhaust stream and sending a

signal corresponding to the temperature in the exhaust stream to the controller, the controller controlling the heater in response to the temperature signal.

6. The system as set forth in claim 1, comprising an oxidation catalyst coating on the filter.

7. A system for treating diesel exhaust gases, comprising:

an engine for producing a diesel exhaust stream;

a diesel particulate filter downstream of the engine and adapted to remove particulates from the exhaust stream;

a heater upstream of the filter adapted to deliver energy to the exhaust stream; and

a NOx reduction catalyst downstream of the heater.

8. The system as set forth in claim 7, comprising an oxidation catalyst coating on the filter.

9. The system as set forth in claim 7, wherein the NOx reduction catalyst includes a catalyst downstream of the DPF.

10. The system as set forth in claim 7, wherein the heater is adapted to elevate the exhaust stream temperature to a temperature in an optimal range for NOx reduction by the NOx reduction catalyst.

11. The system as set forth in claim 10, wherein the heater is adapted to elevate the exhaust stream temperature to a temperature sufficient to cause active regeneration of the filter.

12. The system as set forth in claim 11, comprising a controller for controlling operation of the heater and a temperature sensor for sensing a temperature in the exhaust stream and sending a signal corresponding to the temperature in the exhaust stream to the controller, the controller controlling the heater in response to the temperature signal.

13. The system as set forth in claim 10, comprising a controller for controlling operation of the heater and a temperature sensor for sensing a temperature in the exhaust stream and sending a signal corresponding to the temperature in the exhaust stream to the controller, the controller controlling the heater in response to the temperature signal.

14. The system as set forth in claim 7, comprising a diesel oxidation catalyst upstream of the heater adapted to cause passive regeneration of the filter when the exhaust stream is above a light-off temperature of the diesel oxidation catalyst.

15. A method for treating diesel exhaust gases, comprising:

producing a diesel exhaust stream with a diesel engine;

removing particulates from the exhaust stream with a diesel particulate filter downstream of the engine;

periodically delivering energy from a heater to the exhaust stream upstream of the filter in sufficient amounts to cause active regeneration of the filter; and

periodically heating a diesel oxidation catalyst upstream of the heater to a light-off temperature of the diesel oxidation catalyst to cause passive regeneration of the filter.

16. The method as set forth in claim 15, comprising causing NOx reduction with a NOx reduction catalyst downstream of the heater.

17. The method as set forth in claim 15, comprising sensing a temperature in the exhaust stream and sending a signal corresponding to the temperature in the exhaust stream to a controller for controlling operation of the heater, and controlling the heater in response to the temperature signal.

18. A method for treating diesel exhaust gases, comprising:

producing a diesel exhaust stream with a diesel engine;

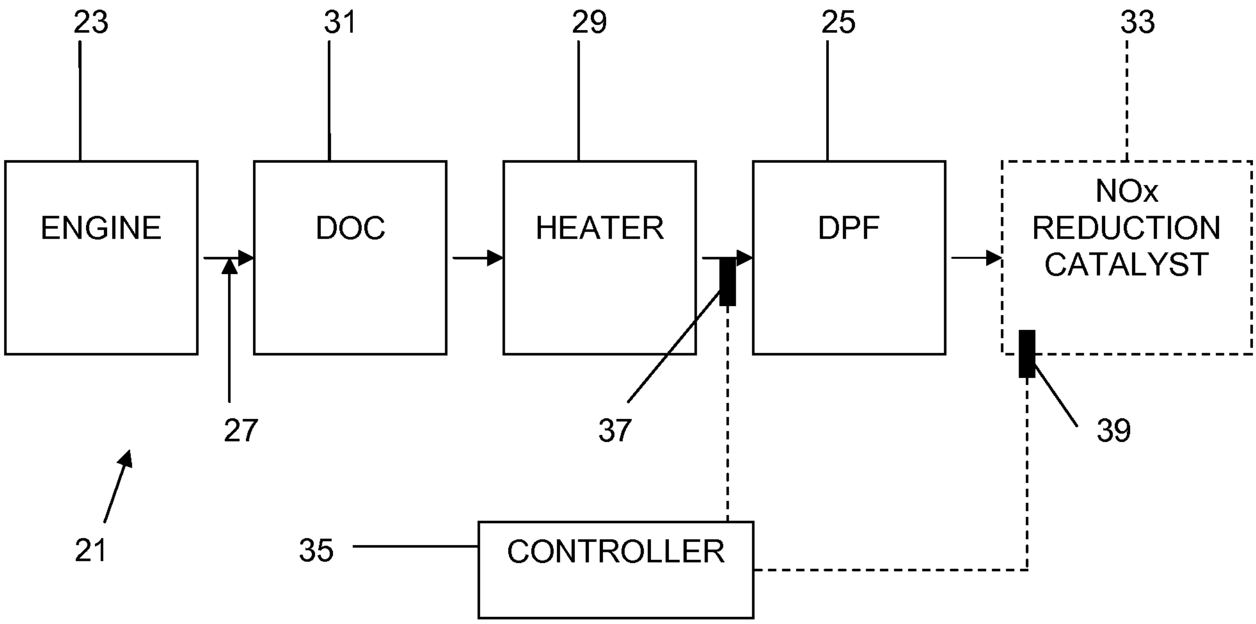
removing particulates from the exhaust stream with a diesel particulate filter downstream of the engine;

causing NOx reduction in the exhaust stream with a NOx reduction catalyst; and

delivering energy from a heater upstream of the NOx reduction catalyst sufficient to raise a temperature of the NOx reduction catalyst to a temperature in an optimal range for NOx reduction by the NOx reduction catalyst.

19. The method as set forth in claim 18, comprising delivering energy from the heater sufficient to elevate the temperature of the exhaust stream to a temperature sufficient to cause active regeneration of the filter.

20. The method as set forth in claim 18, comprising sensing a temperature in the exhaust stream and sending a signal corresponding to the temperature in the exhaust stream to a controller for controlling operation of the heater, and controlling the heater in response to the temperature signal.


23
31
29
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ENGINE
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HEATER
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NOx
REDUCTION
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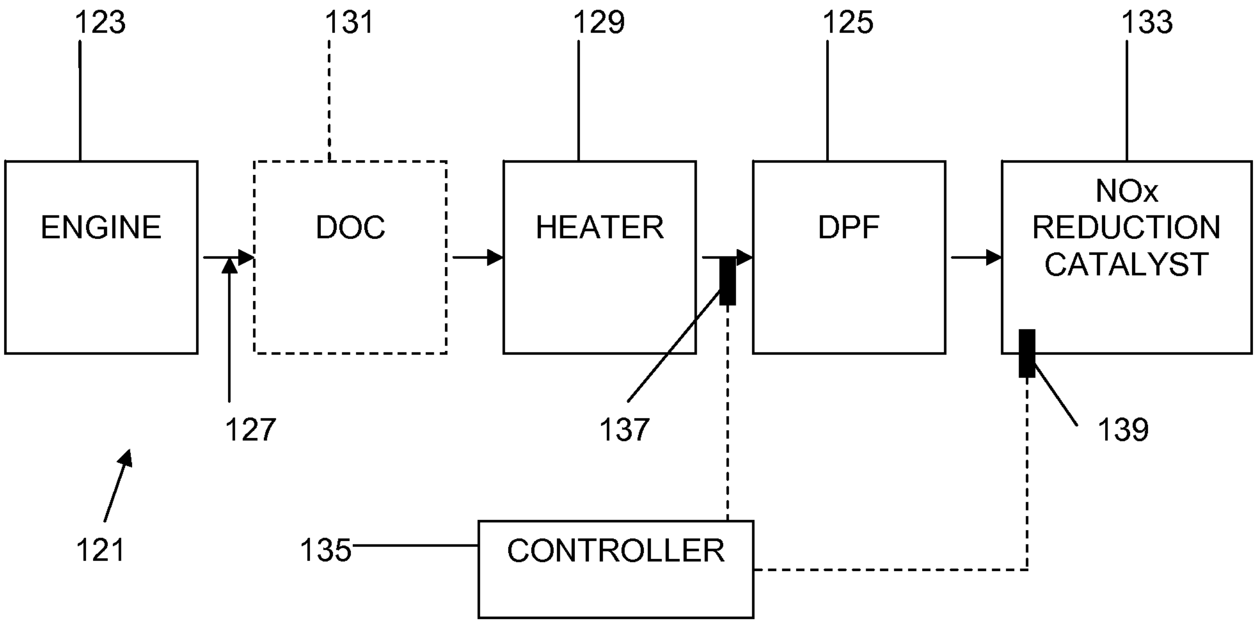
CONTROLLER

FIG. 1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DPF
NOx
REDUCTION
CATALYST
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121
135
CONTROLLER

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/59127

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F01N 3/00; F01N 3/10 (2008.04)
USPC - 60/282; 60/299
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC - 60/282; 60/299

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 60/282; 60/299 (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO WEST (PGPB, USPT, EPAB, JPAB); Google Scholar Search Terms: diesel near3 exhaust) and (Nitrous Oxide or NOx or Nitr$ or Oxygen or Oxy$) and (reduc$) and (gas$) and (engine) and (particulate filter)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2003/0140620 A1 (SHIGAPOV et al.) 31 July 2003 (31.07.2003); para [0002]; para [0009]; abstract; para [0008]; para [0012]; para [0033]; Fig. 2	1-20
Y	US 2007/0245723 A1 (KAMOSHITA et al.) 25 October 2007 (25.10.2007); para [0066]; para [0024]	1-20
Y	US 2007/0245724 A1 (DUBKOV et al.) 25 October 2007 (25.10.2007); abstract	6, 8

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 August 2008 (04.08.2008)	08 AUG 2008

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774